

# The Digestive System

## Embryology Atlas

### Chapter 25: Digestive System Development

by John F. Neas

#### Primitive Gut

The gastrointestinal tract and the accessory digestive organs develop from modifications of the **primitive gut** that forms a continuous elongated tube from the future mouth to the future anus. By the third week, endodermal cells have migrated around the inside of the blastocyst, completing a pouch called the **yolk sac**. The primitive gut, composed entirely of endoderm, develops early in the fourth week when the dorsal part of the yolk sac incorporates into the embryo during the process of folding (see Chapter 28—Embryonic Period). The endoderm of the yolk sac becomes the epithelium of the digestive tract.

Soon thereafter, the mesoderm forms and splits into somatic and splanchnic layers. The splanchnic mesoderm associates with the endoderm of the primitive gut. Thus, the primitive gut is a simple endodermal tube surrounded by mesoderm. Cavities that appear within the mesoderm produce the coelom (ventral body cavity). The endodermal layer of the primitive gut produces the *epithelial lining* and *glands* of most of the gastrointestinal tract. The vascular portion, smooth muscle, connective tissue, and parietal peritoneal develop from *somatic mesoderm*. Visceral peritoneum develops from *splanchnic mesoderm*.

The primitive gut elongates and, at about the latter part of the third week, it differentiates into an anterior **foregut**, a central **midgut**, and a posterior **hindgut**. For a while, the midgut maintains a broad connection with the yolk sac within the **yolk stalk**.

At four weeks, the digestive tube remains suspended in the coelom by **dorsal** and **ventral mesenteries**. The ventral mesentery disintegrates everywhere except where major blood vessels or visceral organs have grown into it. The ventral mesentery remains intact along the path of the umbilical arteries and where the umbilical vein and liver develop.

#### Foregut

The foregut includes the pharynx, mouth (palate, jaws, gums, teeth, tongue, some taste buds, etc.), esophagus, stomach (lining and gastric glands), hepatic cells and bile ductules, gall bladder and common bile duct, pancreatic acinar and island cells, and duodenum (to the common bile duct). (The spleen, discussed in the lymphoid system of which it is a part, develops from a condensation of mesenchyme between the layers of the dorsal mesogastrium.)

The **pharynx**, **esophagus**, **stomach**, and a portion of the **duodenum** develop from the foregut. As development progresses, the endoderm at several places along the foregut develops into hollow buds that grow into the mesoderm. These buds develop into the **salivary glands**, **liver**, **gallbladder**, and **pancreas**. Each

of these retains a connection with the gastrointestinal tract through a duct.

### Oral Cavity

A depression called the **stomodeum (oral pit)** is not part of the foregut but an invagination of ectoderm that will become the oral cavity. A thin **oral membrane**, lined by ectoderm and endoderm, separates the ectoderm of the stomodeum from the endoderm of the foregut. When the oral membrane ruptures at about 24 days, the digestive tract opens outside of the embryo to the amniotic cavity. Thus, structures of the mouth, including the epithelium of the vestibule, gums, and hard palate, develop from surface ectoderm. The posterior oral mucosa develops from foregut endoderm.

### Pharynx

The primitive *pharynx* develops from the foregut. The pharyngeal apparatus consists of arches, grooves, membranes, and pouches. Each **pharyngeal arch** consists of a core of mesenchyme covered externally by ectoderm and containing an aortic arch artery, a bar of cartilage, a nerve, and muscle tissue.

The **pharyngeal pouches** develop from foregut endoderm that lines the pharynx internally. The first pharyngeal pouch produces the **auditory tube**, the lining of the middle ear cavity, and other structures. The second pharyngeal pouch produces the surface epithelium and the lining of the crypts of the **palatine tonsil**. The **inferior parathyroid glands** and **thymus** develop from the third pouch. The fourth pharyngeal pouch produces the **superior parathyroid glands** and **ultimobranchial body**. The thymus and parathyroid glands (superior and inferior) migrate caudally, the thymus to the superior mediastinum, the parathyroid glands to the dorsal surface of the thyroid gland where they embed.

Pharyngeal (branchial) membranes develop from surface ectoderm at the base of the pharyngeal grooves, foregut endoderm of the pharyngeal pouches, and intervening mesoderm. Four pharyngeal membranes develop in the branchial grooves during the fourth week, but only the first persists to become the **tympanic membrane**. Four pharyngeal grooves (clefts) separate the pharyngeal arches on each side during the fourth and fifth weeks. The surface ectoderm of the first pharyngeal groove produces the epithelium of the **external auditory canal**. The other grooves disappear when the second pharyngeal arch overgrows them, forming the **cervical sinus** that later obliterates.

The **thyroid gland** originates as a pharyngeal diverticulum of foregut endoderm near the developing tongue.

### Palate

Fusion of the maxillary swellings produces the **philtrum**, the median part of the **maxilla** in which the four incisor teeth take root, and the triangular **primary palate**. The lateral palatine processes fuse with the primary palate, nasal septum, and each other to form the **secondary palate**. The unossified posterior portions of the lateral palatine processes form the **soft palate** and **uvula**. The epithelium of the soft palate develops from foregut endoderm.

## Teeth

The development of **teeth** involves the formation of dentine, cement, and enamel by **odontoblasts**, **cementoblasts** and **ameloblasts**, respectively. Ameloblasts derive from surface ectoderm. Odontoblasts develop either from head mesoderm (mesenchyme), like cementoblasts, or from neural crest.

## Tongue

The first pharyngeal arch produces two distal tongue buds (lateral lingual swellings) that form the *anterior two-thirds* of the **tongue**, and a median tongue bud (tuberculum impar) that has no identifiable adult derivatives. The ventromedial parts of the second pharyngeal arches fuse to form the copula. Mesoderm in the ventromedial parts of the third and fourth pharyngeal arches produces the hypobranchial eminence. The hypobranchial eminence overgrows the copula, forming the *posterior third* of the tongue. The **epiglottis** develops from a median swelling formed by the posterior part of the fourth arch. **Arytenoid cartilages** develop on the sides of the laryngeal orifice that lies immediately behind the epiglottis. The epithelium of the tongue develops from foregut endoderm.

Some of the tongue muscles probably develop *in situ* from mesenchyme, but most develop from myoblasts that migrate from the occipital myotomes. The connective tissue, lymphatic vessels, and blood vessels of the tongue arise from pharyngeal arch mesenchyme.

The hypoglossal nerve innervates all intrinsic and extrinsic tongue muscles, except *M. palatoglossus* innervated by the vagus nerve. The general sensory innervation of the tongue depends upon pharyngeal arch contribution. The trigeminal nerve (mandibular division) and the glossopharyngeal nerve innervate the anterior two-thirds and posterior one-third of the tongue, respectively. The superior laryngeal nerve (vagus nerve) innervates the epiglottis.

## Taste Buds

**Taste buds** appear at about eight weeks. Generally, they develop from foregut endoderm, but some presumably develop in areas of surface ectoderm. Definitive taste buds replace primitive taste buds before birth. The facial, glossopharyngeal, and vagus nerves innervate the taste buds.

## Salivary Glands

The **salivary glands** arise as solid cellular outgrowths from the wall of the developing mouth into the underlying mesenchyme. These epithelial buds branch repeatedly, forming solid ducts whose ends become secretory acini. The solid ducts and acini later hollow out (canalize). The surrounding mesenchyme condenses and becomes the capsule and divides each gland into lobules. The ducts and acini of the parotid glands develop from surface ectoderm. The ducts and acini of the submandibular and sublingual salivary glands probably develop from foregut endoderm.

## Esophagus

About the end of the fourth week, the tracheoesophageal septum divides the foregut anteriorly into the trachea and lung buds and posteriorly into the esophagus. The epithelium of the esophagus and the esophageal glands develop from foregut endoderm. The smooth muscle of the esophagus, like that of the entire gut, develops from the splanchnic mesenchyme that surrounds the endoderm.

## **Stomach**

The **stomach** first appears about the end of the fourth week as an elongated dilation of the foregut. The **epithelial lining** and **gastric glands** develop from foregut endoderm. Splanchnic mesoderm produces stomach **smooth muscle**, the **lesser omentum**, the **dorsal mesentery** (dorsal mesogaster and greater omentum), and the dorsal mesoesophagus. The dorsal border of the stomach grows more rapidly than the ventral border, forming a distinct curvature.

## **Liver and Biliary Tree**

The pancreas and liver begin as the epithelium of the foregut grows out from the digestive tract and into the dorsal and ventral mesenteries, respectively. The **liver** (liver epithelial cords) and **biliary tree** appear late in the third week or early in the fourth week as the **hepatic diverticulum**, an outgrowth of the ventral wall of the distal foregut (duodenum).

The foregut endoderm of the hepatic diverticulum produces the parenchymal of the liver (**hepatocytes**) and the epithelial lining of the biliary tract. The hepatocytes arrange into a series of branching and anastomosing plates in the mesenchyme of the transverse septum. These plates subsequently intermingle with vitelline and umbilical veins to form **hepatic sinusoids**. Besides contributing to the sinusoids, the splanchnic mesenchyme in the transverse septum also forms the **stroma**, the fibrous and serous coverings (**liver capsule**), the **falciform ligament**, and the blood forming, or hematopoietic tissue (**Kupffer cells**), of the liver. The **connective tissue** and **smooth muscle** of the biliary tract also develops from this mesenchyme.

The hepatic diverticulum experiences incredible growth from the gallbladder, associated ducts, and the various lobes of the liver. The hepatic diverticulum subsequently divides into a small ventral part, the future **gall bladder**, and a larger cranial part, the **liver primordium**; the latter portion grows into the septum transversum and differentiates into the parenchyma of the liver and the lining of the biliary ducts. The bile ducts form as the connection between the hepatic diverticulum and the foregut (duodenum) narrows when strands of hepatocytes penetrate the septum transversum. The bile duct has a small ventral outgrowth that becomes the **cystic duct** and expands into the gallbladder. Once developed, the hepatic and cystic ducts connect to the duodenum by the **common bile duct**. The entrance of the bile duct into the small intestine gradually shifts from an initial anterior position to a posterior one and passes behind the duodenum.

By the sixth week, the liver performs hematopoiesis (the formation of blood cells). The liver represents 10% of the total weight of the fetus by the ninth week.

As the embryo enlarges, the stomach and liver rotate to the right, producing two pockets. The mesenteries that form these pockets are the **greater omentum** and **lesser omentum**.

## **Pancreas**

The pancreas develops from dorsal and ventral pancreatic buds that arise from the caudal part of the foregut. The dorsal bud appears during the fourth week opposite the hepatic diverticulum. The ventral pancreatic primordium appears during the fifth week, either as an outgrowth of the hepatic diverticulum or separately from the duodenum. The dorsal pancreatic bud grows more rapidly than the ventral and soon extends dorsally behind the duodenum into the dorsal mesentery. The duodenum grows and rotates to the right (clockwise) and carries the ventral pancreatic bud to the dorsal mesentery where it fuses with the dorsal bud during the seventh week. The dorsal bud forms the body and tail of the pancreas; the ventral bud forms the uncinat process and most of the head of the pancreas. Foregut endoderm produces the pancreatic acinar and island cells.

## **Duodenum**

The caudal part of the foregut and the cranial part of the midgut form the C-shaped loop of the duodenum. The junction of the two embryonic parts in the adult is immediately distal to the orifice of the common bile duct. The lining and smooth muscle of the duodenum develop from foregut endoderm and splanchnic mesoderm, respectively.

## **Midgut**

The endoderm of the midgut produces the lining of the digestive tract from the foregut to the middle of the transverse colon. The midgut opens into the yolk sac until the fifth week. After that time, the yolk sac constricts, detaches from the midgut, and the midgut closes. By the fifth week, the midgut elongates into a ventral U-shaped midgut loop and, with the breakdown of the ventral mesentery, the loop projects into the umbilical stalk. Additional elongation and coiling occur outside the body of the embryo.

As development continues, the anterior limb of the midgut loop coils to form most of the small intestine. The posterior limb of the midgut loop enlarges to form portions of the small and large intestines. The two loops combined produce the **duodenum** (distal to the common bile duct), **jejunum**, and **ileum**. A **cecal diverticulum** appears during the fifth week.

The intestines have begun withdrawing back into the coelomic (future abdominal) cavity during the tenth week, but they continue to grow longer and further differentiation and rotation occur. The cecal diverticulum continues to develop, producing the **cecum** and **appendix**. The remainder of the midgut produces the ascending colon and. right (proximal) half to two-thirds of the **transverse colon** (hepatic flexure).

The smooth muscle of the midgut and the dorsal mesentery of the large and small intestines develop from splanchnic mesoderm.

## **Hindgut**

The endoderm of the hindgut produces the lining and glands of the gastrointestinal tract from the distal end of the midgut to the upper part of the anal canal. This includes the left third to one-half of the **transverse colon**, the **descending** and **sigmoid colon**, the **rectum**, and the upper part of the **anal**

**canal.** The remaining mucosa and glands of the anal canal develop from the proctodeum.

The hindgut extends into the caudal part of the embryo where it forms a large chamber, the **cloaca**. The **allantois**, a tubular extension of the cloaca that receives urinary wastes from the fetus, projects from the body and into the **body stalk**. Fusion of the yolk stalk and body stalk produce the **umbilical stalk**, or **umbilical cord**.

The hindgut extends from the midgut to the **cloacal membrane** that separates the hindgut from the proctodeum. The **proctodeum (anal pit)** is an invagination of surface (epidermal) ectoderm that develops in the hindgut and develops into the anus. The cloacal membrane ruptures making the hindgut continuous with the outside of the embryo through the anus.

A band of mesenchymal cells called the **urorectal septum** grows caudally during the fourth through seventh week until it forms a complete partition that separates the cloaca into the dorsal (posterior) anal canal and ventral (anterior) **urogenital sinus** that retains connection to the allantois. With completion of the urorectal septum, the cloacal membrane is separated into an anterior **urogenital membrane** and a posterior **anal membrane**. The anal membrane ruptures toward the end of the seventh week to form the anal opening that is lined with ectodermal cells. About this time, the urogenital membrane ruptures to provide further development of the genital and urinary systems.

Foregut

Tongue

Esophagus

Stomach

### **Liver and Biliary Tree**

Liver histology

Gallbladder histology

### **Pancreas**

Pancreas development weeks 5-7

Exocrine pancreas histology

Duodenum

Midgut

Hindgut